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AUTHOR(S) J. R. Bartlit, MST-3
J. L. Anderson, MST-3
V. G. Rexroth, MST-7

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Los Alamos National Laboratory
Los Alamos, New Mexico 87545

SUBSYSTEM COST DATA FOR THE TRITIUM SYSTEMS TEST ASSEMBLY*

John R. Bartlit, James L. Anderson, and V. G. Rexroth
Los Alamos National Laboratory
P.O. Box 1663, MS-C348
Los Alamos, NM 87545

ABSTRACT

Details of subsystem costs are among the questions most frequently asked about the $14.4 million Tritium Systems Test Assembly (TSTA) at Los Alamos National Laboratory. This paper presents a breakdown of cost components for each of the 20 major subsystems of TSTA. Also included are details to aid in adjusting the costs to other years, contracting conditions, or system sizes.

I. INTRODUCTION

The purpose of the Tritium Systems Test Assembly (TSTA) at Los Alamos National Laboratory is to develop and demonstrate the deuterium-tritium fuel processing systems and associated safety and environmental protection systems required for commercial-scale fusion power reactors.[1] In addition to data on systems design, operation and reliability, data of interest to be furnished the fusion community by TSTA include data on subsystem costs to allow informed planning and budgeting for future machines.

Expenditures at TSTA totaled $14.4 million between the start of the project in January 1977 and the end of major construction in October 1982. This total included building modifications, design, all capital equipment, and about 90 man-years of effort in management and staff for process design, analysis, small fabrication, and partial development of control software. The detailed breakdown and explanation of these costs for 20 subsystems is the subject of this paper. The 90 man-years of staffing (worth $5.2 million) were allocated to the project as a whole with no effort to ascribe portions to individual subsystems.

Also included is information that will be useful in extrapolating the costs to different situations, for example, different years or system sizes.

II. BRIEF DESCRIPTIONS OF SUBSYSTEM FUNCTIONS

Costs are broken out in Table I for the capital and installation costs of subsystems at TSTA. A few words are necessary to explain the general configuration and function of equipment in each subsystem. Further details on components in each subsystem are contained in Table II. Table II also has literature references to more complete descriptions previously published on some of the major subsystems.

In order of the subsystem numbers shown in the tables, the TSTA subsystems function as follows:

1. Chamber evacuation is the pump train that removes the spent fuel mix and impurities from the reaction chamber.

2. Transfer pumps are those that circulate the fuel mix for processing at about one atmosphere pressure.

3. Fuel cleanup processes the spent fuel to remove gaseous impurities and decomposes them to recover tritium and deuterium for reuse.

4. Isotope separation is four, interlinked, cryogenic distillation columns that produce four streams - HD, D_2, T_2, and DT - of high isotopic purity.

5. Storage beds are beds of activated uranium for gettering and storing a maximum of 37 g. mole of hydrogen isotopes each.

6. Gas analysis is the system (primarily gas chromatographs) for analyzing concentrations of impurities (H_2O, Ar, NH_3, CO_2, CO, and CH_4) and H and D throughout the process flow loop.

7. Tritium monitoring includes mainly ionization chambers for monitoring the room, gloveboxes, the stack and duct to the stack.

8. Secondary containment is the gloveboxes and their operational controls.

9. Tritium waste treatment processes glovebox atmospheres to capture tritium.

10. Emergency room cleanup processes the room atmosphere to capture tritium.

11. Building ventilation controls room pressures and air flow routinely and in case of accidental tritium release.

12. Data acquisition and control includes two redundant process computers and two safety computers plus interfacing with the process, wiring, and many instruments.

13. Uninterruptable power is a battery supply mainly to keep the computers and tritium monitoring instruments operational.

14. Emergency generator provides backup power.

15. Solid waste disposal is a glovebox for handling and packaging solid wastes in preparation for disposal.

16. Inventory control is a glovebox with standard-volume tanks to which hydrogen isotopes from the TSTA process loop are pumped at least semi-annually for accounting purposes.

17. Experimental contamination laboratory is a small, off-line facility for experiments on tritium barriers and decontamination methods.

18. Utilities include the particular mechanical and electrical services needed in a building that previously had these general services.

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19. Physical plant included the disposal of old equipment, and new roofing, fencing, control room air conditioning, parking lots, and fire protection.

20. Impurity simulation adds the impurities expected in the exhaust gases from a tokamak reactor. This subsystem is not needed in applications involving real reactors.

III. EXPLANATORY COMMENTS ON TABLES

Tables I, II, and III contain the subsystem cost data, together with additional information useful for adjusting the costs to other situations. The additional information includes: years in which major expenditures occurred, whether work was done in-house or by outside contract, details on components of cost included or excluded (Table II) and information for helping estimate costs for different size, but similar, systems (Table III). Table IV summarizes the overall total costs for TSTA.

All process design was done in-house and the cost of design is included in the $5.2 million cost for TSTA staff (see Sec. I.). The cost of mechanical design for items contracted outside appears in the capital cost and for items done in-house is included either in TSTA staff cost or in "installation design and inspection" (Table IV). Fabrication costs for basic crafts, contracted items, and major shop work are included in the capital or installation costs. Small, specialized fabrication was done by staff technicians and the cost is included in staff cost.

The cost of all gloveboxes except those associated with subsystems #4 and #15 is included in secondary containment (subsystem #8). The cost of most subsystem instrumentation is included in data acquisition (subsystem #12) except for instrumentation for the two, major contracted subsystems (subsystems #3 and #4), which were delivered complete with instrumentation.

Essentially all gas analysis and tritium monitoring, even if associated with another subsystem, was costed as part of the analysis subsystems (#6 and #7).

The intent of this paper is to present costs for construction, but not operation, of the TSTA. However, the line between the two, looked at either by time or activity, is not always clearly defined. Examples of ambiguous tasks are rectification of hardware deficiencies uncovered during checkout, and control software development. A few costs that could be listed under construction are not accounted for in the tables. These are the cost for writing control software for some individual process systems (design of the major and higher order control software is included in staff cost) and the cost for installation of some intersystem process tubing (mainly 1/4-in. tubing connecting gloveboxes). Other costs not appearing in the tables are the cost of five gloveboxes without controls and the cost for sufficient (2000+ gal.) liquid nitrogen storage dewars, which TSTA obtained free of charge from sources of surplus equipment.

IV. COST TABLES

Table I

Capital and Installation Costs of Subsystems

Subsystem	Capital cost $K	Yr. of major cap. expend.	Mech. design and fab.	Installation cost* $K
1. chamber evacuation	200	1978-79	commercial parts + in-house	73
2. transfer pumps	111	1977	commercial pumps	112
3. fuel cleanup	1,000	1980	industrial contract	70
4. isotope separation	1,237	1978	industrial contract	63
5. storage beds	60	1981	in-house	10
6. gas analysis	119	1979	commercial instruments	26
7. tritium monitoring	193	1978-82	commercial parts + in-house	33
8. secondary containment	182	1978-82	commercial boxes	30
9. tritium waste treatment	343	1980-81	commercial parts + in-house	69
10. emergency room cleanup	382	1979-80	commercial parts + in-house	357
11. building ventilation	154	1978-79	contract	--
12. data acquisition & control	1,379	1979-81	commercial	531
13. uninterruptable power	95	1980	commercial units	44
14. emergency generator	100	1980	commercial unit	168
15. solid waste disposal	23	1980	commercial parts	--
16. inventory control	25	--	in-house	13
17. experimental contamination laboratory	54	1981	commercial parts	94
18. utilities	378	1977-78	laboratory contractor	--
19. physical plant	730	1977-78	laboratory contractor	--
20. impurity simulation	26	--	in-house	--
TOTAL	6,791			1,693*

*Installation design and inspection not included; see Table IV.

Table II

Components Included and Excluded in Subsystem Costs

Subsystem	Lit. ref.	Components included	Components excluded
1. chamber evacuation	2.	reference system, secondary containment, 1 cryopump + tests, scroll pump, blower, turbo	other cryopumps
2. transfer pumps	3.	reference system, 12 metal-bellows pumps, 100 valves, 20 pressure transducers, 1 scroll pump	
3. fuel cleanup	4.	reference system, instruments, instrumentation & control, control software, integrity test	glovebox, software, guaranteed purification
4. isotope separation	5.	reference system, refrigerator, (420 W @ 20K), integrity test, LN_2 distribution system	guaranteed separation; LN_2 storage dewars (no charge)
5. storage beds		beds, heaters, instrumentation & associated plumbing	vacuum pump
6. gas analysis		instrument data stations, sample lines	calibration gas apparatus
7. tritium monitoring		ion chamber + electronics for room, glovebox, duct, & stack monitor	
8. secondary containment		6 boxes; O_2 & pressure instrument & controls for 13 boxes	T_2 monitors, 5 boxes obtained free, 2 boxes with other subsystems
9. tritium waste treatment		compressor, catalytic oxidizer, driers, instrumentation for processing glovebox atm.	
10. emergency room cleanup	6.	reference system, spare compressor	
11. building ventilation		special valving, blower, ducts, stack	heating and ventilating units existed
12. data acquisition & control	7.	reference system, computers, signal conditioners, wiring, some instrumentation	some major subsystem instrumentation
13. uninterruptable power		units, instrumentation & controls for 1/2 hour power @ 100 kw	
14. emergency generator		protective shed, unit, instrumentation & controls for 30 hr. power @ 750 KVA	
15. solid waste disposal		glovebox & fume hood	storage drums, burial
16. inventory control		standard volume, pressure standard, instrumentation, valving	dynamic (on-line) accounting instrumentation

Table II (cont)

Components Included and Excluded in Subsystem Costs

Subsystem	Lit. ref.	Components included	Components excluded
17. experimental contamination laboratory		dedicated cleanup system	T_2 monitors
18. utilities		mechanical & electrical service in building	service to building
19. physical plant		old equipment removal, building preparation, roof, fence, fire, control room heating and ventilation	building existed
20. impurity simulation		flow valves, instrumentation	

Table III

Approximate Dependence of Costs on System Size

Subsystem	Parameter for scaling	TSTA value of scaling param.	Comments on cost as f(size)
1. chamber evacuation	pumping speed	$16\frac{m^3}{s}(H_2)+3\frac{m^3}{s}(He)$	modular; cost is proportional to total speed
2. transfer pumps	no. of pumps	12 metal bellows pumps	modular, per pump
3. fuel cleanup	fuel flowrate	360 $\frac{\text{g mol DT}}{\text{day}}$	cost is nearly independent of $\pm$ 3 to 5-fold flow change
4. isotope separation	fuel flowrate	360 $\frac{\text{g mol DT}}{\text{day}}$	cost is nearly independent of $\pm$ 3-fold flow change
5. storage beds	no. of units	6	modular, per unit
6. gas analysis	no. of instr.	10 gas chromatograph + 1 infrared analyzer	modular, per instrument
7. tritium monitoring	no. of instr.	50	modular, per instrument
8. secondary containment	contained volume	13 boxes (6 bought) $\approx 2\frac{m^3}{box} = 26\,m^3$	boxes (w/o controls) = \$4000/m^3 (1980\$)
9. tritium waste treatment	processing rate	50 CFM	scales with glovebox atm. flowrate
10. emergency room cleanup	air processing rate	1500 CFM	scales with room volume and cleanup time
11. building ventilation	air flowrate	7500 CFM main cell 7500 CFM offices	
12. data acquisition & control	complex		
13. uninterruptable power	complex	100 KW	
14. emergency generator	complex	750 KVA	
15. solid waste disposal	--		
16. inventory control	none		independent of system size
17. experimental contamination laboratory	none		
18. utilities	--		
19. physical plant	--		
20. impurity simulation	none		

Table IV

Total Cost Summary for TSTA

Item	$K	
capital expenditures	6,791	
laboratory capital overhead	286	
installation	1,693	
installation design & inspection	450	
project staff (1977-82)	5,200	
Total: design & major construction	14,420	= $14.4 million

V. SUMMARY

This paper has presented costs, broken out by subsystem, for designing and constructing the TSTA. Also included is information useful for adjusting the costs to other situations, such as to different years or different size, but basically similar, systems.

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